ABSTRACT

An original router bit with CrN coating on the flank face - Advanced Material Technology - was developed and its performance in surface finish of solid wood was investigated. The end surface of air-dried specimen of oak and beech was cut with this tool at 18,000 rpm and at a maximum feed speed of 3m/min. The machined surface was finished by an ordinary painting process but with/without sanding process before the painting. Microscopic observations of the cross section of the specimen showed that wood tissues are cut sharply by the Advanced Material Technology tool, and there was less fuzzy grain accompanied by the distortion of the wood tissues compared to conventional tools with cemented carbide alloy (UH). The surface roughness parameter Spk of the machined surface by Advanced Material Technology tool was smaller than the one by UH tools. No significant difference was found in the parameters Spk and specular glossiness among the surfaces, one painted after machining by Advanced Material Technology tool and sanding, one painted without sanding, one painted after machining by UH tool and sanding, respectively. The tool life of the Advanced Material Technology tool was about five times longer compared to conventional tools. The finishing process of solid wood furniture without sanding process can be realized by using the Advanced Material Technology tool.

INTRODUCTION

The surface finishing process consists of the repetition of sanding, painting, removing and drying which are the most important processes in furniture production, especially for the production of solid wood furniture. The role of sanding is to remove surface defects such as waviness, scratch, torn grain, fuzzy grain and burn-out to achieve a smooth and fine surface. The quality of the finished surface depends on the sanding technique of skilled workers. However, this process requires much time and labor and is normally accompanied by a bad working environment with fine air-borne dust. There have been many trials to develop automatic sanding machines and robots, however they were not always successful and the full automatic sanding process has not been realized yet.

FEATURES OF THE ADVANCED MATERIAL TECHNOLOGY TOOL

An extremely thin and hard layer on the tool surface can be achieved by the coating of the Advanced Material Technology. We form this layer of less than 10μm in thickness on both faces of the base cutting edge made of cemented carbide alloy, flank face and bevel face, respectively. The coated layer makes the tool surface harder than conventional tools made of cemented carbide alloy. The radius of the cutting circle is less than 1μm and the cutting edge is sharper than a conventional one with a cutting circle of about 3μm utmost, so that a fine machined surface can be realized for a longer time.

We have developed a original wood cutting tool with Advanced Material Technology coated flank face. The cutting edge is sharper and harder than the conventional tools made of cemented carbide alloys. The tool can produce a very fine surface without fuzzy or torn grain by cutting with this sharp edge. At the same time its tool life is much longer due to its hard coated layer showing a unique wear process called “self-grinding effect”.

We have applied this tool to a router bit to finish solid wood furniture parts and evaluated the surface quality of the machined surface to confirm the possibility to omit the sanding process.

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despite of the advance of the wearing process. On the contrary, the apparent sharpness angle decreases as the wearing process advances. We call this phenomenon "self-sharpening effect".

Test Machine and Cutting Condition

The router bit was attached to the main spindle of a CNC router and rotated at a spindle speed of 18,000 rpm. The specimen set on the XY-table was fed at the speeds, 0.5, 2.0 and 3.0 m/min respectively, and the end surface of the board was cut at the depth of cut of 1 mm in down-milling direction.

Cutting Tool

Figure 4 shows the router bit with two straight cutting edges with Advanced Material Technology ready for the experiment. Another tool of the same dimension - but made out of cemented carbide alloy (UH) - was also employed. Rake angle, peripheral relief angle and lead angle of the tools were 0, 20 and 10 degrees, respectively.

Painting Process

A part of the specimen machined by the tools - Advanced Material Technology tool and UH - were sanded by a coated abrasive P220 and transferred to the painting process consisting of 6 steps, under coating, sealer coating, intermediate sanding with coated abrasive P400, color coating and finishing clear coating. All the painting processes were conducted by using a spraying gun.

Evaluation of Surface Quality

The performance of the tools was evaluated by the quality of the machined surface. For some cutting conditions, the surface finished by a worn edge after 500 times board cuttings was also evaluated. The surface quality of the machined and painted surface was evaluated by the following methods;

1) Microscopic observation with CCD micro color camera and SEM
2) Estimation of surface roughness by stylus method: An area of the machined surface of 5 by 5mm was scanned by a stylus apparatus (Form Talysurf PGI S6, Taylor Hobson Ltd.) . The data was taken at an interval of 0.01mm in both directions parallel and perpendicular to the scan direction. Some roughness parameters including three dimensional ones were calculated.
3) Estimation of glossiness of painted surface: Specular glossiness of the machined or painted surface was evaluated by a glossiness meter according to JIS Z 8741(1997).
4) Visual evaluation by skilled worker:
The quality of the machined or painted surface was evaluated by a skilled worker by visual inspection or by touching with fingers.

RESULTS AND DISCUSSION

Quality of Machined Surface

Figure 6 shows the cross section of the machined surface of oak observed by CCD camera. In the surface achieved by the Advanced Material Technology tool, vessels are cut across sharply, and their aperture can clearly be observed on the machined surface. On the contrary, the rims of the vessel apertures appeared on the surface machined by the non-coated tool UH were distorted and unclear, and the apertures were stuffed with small particles. The area around the vessels of the surface made by the UH tool is fuzzier in comparison with the one by the Advanced Material Technology tool. This can be confirmed more clearly by the SEM photographs in Figure 7.

The surface parameter Rpk - named reduced peak height - prescribed in ISO 13565-2 (1996) is the average height of the protruding peaks above the roughness core profile. Therefore the parameter, which do not include effect of the local deeper valleys, is one of the most suitable roughness parameters for the materials who have deeper local valleys like scratches on the painted surface or vessels appearing on machined wood surface. In this study the roughness of the machined surface is evaluated by Spk that is calculated in the same manner as Rpk but in three dimensions. The values of Spk for the surface machined by the Advanced Material Technology tool are smaller than these by UH, especially in the case of oak specimen as Figure 8 shows. This means, the Advanced Material Technology tool can make the surface smoother than a UH tool.

The vessel aperture stuffed with fine particles and the distortions of the wood tissues remaining on the machined surface were observed frequently in the case of the lower feed speed. They have an effect of diminishing the local deeper valleys from the surface and making the apparent surface roughness small. This can be confirmed by the fact that the Spk value is significantly smaller for feed speeds of 0.5m/min than for 2m/min of oak specimen.

Quality of Painted Surface

The Spk values of the surface finished by painting after the combination of two processes, cutting with the Advanced Material Technology tool and sanding, were larger than the ones painted, but without sanding (Figure 9). Microscopic observation shows many shallow scratches generated by the abrasive grain remain on the painted surface, and they made the surface rougher. No significant difference was observed in specular glossiness of the painted surface between the process with sanding and the one without sanding (Figure 10). This suggests the surface can be finished without sanding as the pre-process before the painting, if the surface is machined by a Advanced Material Technology tool. The evaluation by skilled workers has also confirmed this suggestion.
Influence of tool wear on surface quality

Figure 11 shows the change in power consumption in the machine using Advanced Material Technology finger cutters associated with the cutting length. The power consumption for the coated tool lies in a constant level up to the cutting length of 100m, whereas the consumption for the conventional tool increased significantly. Figure 12 and 13 show the Spk and glossiness values of the three types of the painted surfaces, respectively.

There are the painted surface without sanding after the machining with UH tool, the one painted after the machining with UH Tool and sanding (conventional process), and the one painted without sanding after the machining with an Advanced Material Technology tool, respectively. All the machined surfaces were created by worn tools after 500 cuts. There was no significant difference among the three conditions, and this suggests, the finishing process of the combination of the machining with an Advanced Material Technology tool and the painting process without sanding as the pre-process can be introduced into the practical production lines of the solid wood furniture making.

**ADVANTAGES OF COATED TOOLS**

This study suggested the feasibility of the Advanced Material Technology tools to create extremely smooth surfaces of solid wood and to omit sanding process as a pre-processing before painting in furniture production. The advantages to omit sanding are as follows:

- save time and cost of sanding
- improve the work environment by eliminating fine airborne dust and
- improve the quality of painting.

An innovative and novel production strategy will be realized by introducing the Advanced Material Technology tool, although more basic researches are still necessary to confirm and improve the performance.

**References**